Clin Orthop Relat Res (2011) 469:1391–1400
DOI 10.1007/s11999-011-1804-3

SOCIETY AWARDS

2010 Mid-America Orthopaedic Association Physician in Training Award

Predictors of Early Adverse Outcomes after Knee and Hip Arthroplasty in Geriatric Patients

Carlos A. Higuera MD, Karim Elsharkawy MD, MRCS, Alison K. Klika MS, Matthew Brocone BS, Wael K. Barsoum MD

Received: 25 January 2010 / Accepted: 31 January 2011 / Published online: 23 February 2011

Abstract

Background Geriatric patients experience more adverse events owing to early complications after TKA or THA related to preexisting comorbidities. However, associations between patient and surgery variables, including age, BMI, and comorbidities with complications are unclear. Knowing these relationships is necessary for developing risk stratification, defining contraindications, and predicting complications and adverse outcomes.

Questions/purposes We wished to establish and quantify the associations among age, BMI, comorbidities, and type of surgery and anesthesia with complications and early adverse outcomes including longer length of stay, disposition to an extended care facility, readmission, and reoperation in geriatric patients undergoing TKA and THA.

Patients and Methods We prospectively followed a cohort of patients older than 65 years undergoing TKA or THA. Demographics, comorbidities, complications, discharge disposition, readmission, and/or reoperation information within the 90-day postoperative period were collected. Adjusted hierarchical stepwise multivariable regression models were used to analyze associations and relative risks with complications, length of stay, disposition, readmission, and reoperation rates.

Results Patients were approximately 40% more likely to have any complication per each subsequent 10 years of age. Patients who underwent bilateral TKAs were 65% more likely to have any type of complication. Patients who had epidural anesthesia were 2.6 times more likely to have a major systemic complication. Patients with coronary artery disease were more likely to have a transfusion, more likely to have major local complications, including joint infection and/or a major systemic complication, and more likely to require a reoperation after TKA.

Conclusions Age, type of surgery, anesthesia, and other comorbidities, mainly coronary artery disease and chronic heart failure, were associated with complications and adverse outcomes. We believe these risk factors should be used to counsel patients and make preoperative surgical decisions.

Level of Evidence Level II, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

One or more of the authors (WKB) has received funding from the American Geriatrics Society - Dennis W. Jahnigen Career Development Scholars Award. The investigators retained full independence in the conduct of this research. One author (WKB) certifies that he has or may receive payments or benefits from a commercial entity (Stryker Orthopaedics (Mahwah, NJ), Wright Medical (Arlington, TN), Shukla Medical (Piscataway, NJ), Otismed (Alameda, CA), Exactech (Gainesville, FL). One or more of the authors (WKB) has received research funding from Stryker Orthopaedics (Mahwah, NJ), Zimmer (Warsaw, IN), Salient Surgical Technologies (Portsmouth, NH), Cool Systems (Alameda, CA), Orthovita (Malvern, PA), and Brand X (Tucson, AZ).
Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at the Department of Orthopaedic Surgery, Cleveland Clinic, Cleveland, OH, and School of Medicine, Case Western Reserve University, Cleveland, OH.

C. A. Higuera, K. Elsharkawy, A. K. Klika (✉), W. K. Barsoum
Department of Orthopaedic Surgery, Cleveland Clinic,
9500 Euclid Avenue–A41, Cleveland, OH 44195, USA
e-mail: klikaa@ccf.org

M. Brocone
School of Medicine, Case Western Reserve University,
Cleveland, OH, USA

Introduction

Degenerative joint disease is one of the most common conditions affecting the geriatric population in the United States [21, 32, 38, 43]. Total joint arthroplasty (TJA), including primary TKA and THA, are treatment options that enhance function, provide pain relief, and allow increased activities of daily living [6, 28, 37]. Unfortunately, although many patients experience these improvements after TJA, some geriatric patients experience worsening of preexisting medical conditions and overall quality of life owing to different types of postoperative complications [5, 13, 17, 22, 27, 37]. Furthermore, mortality rates in geriatric patients compared with procedure-matched patients after TJA are higher owing to postoperative complications [14, 17, 19, 29]. Most of these complications occur early during the postoperative period and are more common within 90 days after surgery [30, 34].

Aging and some preexisting medical conditions or comorbidities have been associated with increased complications and mortality after TJA [1, 36, 40, 46, 47]; however, a more specific quantified association that includes all the patient and surgical factors with early postoperative complications and other adverse outcomes such as longer length of stay (LOS), need for an extended care facility, readmission, and reoperation has yet to be established. We hypothesized older age, increased body mass index (BMI), and a broad array of common comorbidities in geriatric patients (older than 65 years) undergoing TKA and THA may have a specific association with higher risk of early complications and other adverse outcomes after surgery. Other adverse outcomes include increased hospital LOS, disposition to an extended care facility, and hospital readmission and/or reoperation.

Increasing volume and expenditure for TJAs in this population [7, 20] call for better identifying patients at high risk of morbidity and mortality, improving timing for these procedures, reducing risks associated with these interventions, identifying contraindications, and designing pathways for patient education, rehabilitation, and recovery. To improve the selection of patients and timing for TJAs and reduce the associated risks, it is imperative to identify which patient and surgical variables or factors play a role in the prediction of postoperative clinical outcomes. Some of these factors may be modified before surgery, reducing the overall associated risk of complications developing and other adverse outcomes in this population.

We therefore tested specific patient and surgical factors for associations with early adverse outcomes (ie, longer hospital LOS, disposition to an extended care facility, and need for hospital readmission and/or reoperation) and complications in geriatric patients after TJA. Variables tested included age, gender, BMI, comorbidities (grouped comorbidities as reflected by the Charlson Comorbidity Index (CCI) and single comorbidities), surgical procedure, and anesthesia type.

Patients and Methods

We identified a cohort of 502 patients older than 65 years who underwent 550 TKAs or THAs in a large regional health system in the northeast Ohio area from January 2008 to September 2008. These patients were identified using a query of the hospital-based Operating Room Information System and Current Procedural Terminology codes for patients scheduled for a primary THA (27130) or TKA (27447). The surgeries consisted of 304 TKAs, including 48 bilateral (BL) TKAs, and 198 THAs. There were 188 males (38%) and 314 females (63%), with average ($\pm$ SD) ages of 73.5 ± 6.6 years and 73.5 ± 6.2 years, respectively. The average BMIs were 30.3 ± 4.5 and 30.5 ± 6.5, respectively. The main preoperative diagnosis was osteoarthritis (94%); other diagnoses included avascular necrosis (2.4%), rheumatoid arthritis (2.2%), gout (0.4%), combined osteoarthritis and avascular necrosis (0.4%), and psoriatic arthritis (0.2%) (Table 1). We obtained prior Institutional Review Board approval.

The types of anesthesia used were spinal (72%), epidural (16%), general (12%), or combined (general with epidural) (0.2%) (Table 1). THAs were performed with the patient in a lateral position using either a posterior or anterolateral approach. TKAs were performed with the patient under tourniquet using a medial parapatellar arthrotomy or subvastus approach. Cementless prostheses were used for the THAs and cemented prostheses were used for the TKAs. All patients received preoperative prophylactic intravenous antibiotics that were continued for less than 24 hours after surgery.

All patients received symptomatic pulmonary embolism (PE) prophylaxis following the American Academy of Orthopaedic Surgeons clinical guidelines [2]. Patients at standard and elevated risk of PE and standard risk of bleeding were prescribed enoxaparin, 40 mg subcutaneous daily (for THA) and 30 mg subcutaneous twice a day (for TKA) on postoperative Day 1 and were maintained on this chemoprophylaxis for 3 weeks. When patients received epidural anesthesia, this chemoprophylaxis was started 6 hours after the epidural catheter was removed on postoperative Day 2. Patients at standard risk of PE and at elevated risk of major bleeding were given enteric coated aspirin, 325 mg orally twice a day on postoperative Day 1 and were maintained on this chemoprophylaxis for 6 weeks. Patients receiving warfarin before surgery were restarted on this medication the night of surgery and

Table 1. Patient demographics in the whole cohort and according to type of surgery

Variable	Whole cohort	TKA	Bilateral TKAs	THA
Number of patients	502	256 (51%)	48 (10%)	198 (39%)
Age (years)	74 ± 6.3	74 ± 6.3	72 ± 5.9	74 ± 6.5
	range, 65–94 (73.1, 74.2)	range, 65–89 (73.1, 74.6)	range, 65–87 (70.7, 74.1)	range, 65–94 (72.8, 74.6)
Gender				
Male	188 (38%)	94 (37%)	18 (38%)	76 (38%)
Female	314 (63%)	162 (63%)	30 (63%)	122 (62%)
Body mass index	30.4 ± 6	31 ± 5.6	30.5 ± 5.8	29.7 ± 6.5
	range, 16.8–57.6 (29.9, 30.8)	range, 18.6–45.6 (30.3, 31.6)	range, 20.8–44.9 (28.9, 32.2)	range, 16.8–57.6 (28.8, 30.7)
Diagnosis				
Osteoarthritis	474 (94%)	298 (97%)	47 (98%)	179 (90%)
Avascular necrosis	12 (2.4%)	0	0	12 (6%)
Rheumatoid arthritis	11 (2.2%)	6 (2%)	1 (2%)	4 (2%)
Gout	2 (0.4%)	2 (1%)	0	0
Combined (OA/AVN)	2 (0.4%)	0	0	2 (1%)
Psoriatic arthritis	1 (0.2%)	0	0	1 (1%)
Anesthesia				
Spinal	361 (72%)	163 (64%)	25 (52%)	173 (87%)
Epidural	81 (16%)	64 (25%)	17 (35%)	0
General	58 (12%)	27 (11%)	6 (13%)	25 (13%)
Combined (general/epidural)	2 (0.4%)	2 (0.8%)	0	0
CCI				
0	171 (34%)	81 (32%)	19 (40%)	71 (36%)
1	129 (26%)	64 (25%)	10 (21%)	55 (28%)
2	101 (20%)	51 (20%)	11 (23%)	39 (20%)
3	55 (11%)	33 (13%)	3 (6.2%)	19 (9.6%)
4	21 (4.2%)	11 (4.3%)	4 (8.3%)	6 (3.0%)
5	14 (2.8%)	9 (3.5%)	1 (2.0%)	4 (2.0%)
6	6 (1.2%)	4 (1.6%)	0	2 (1.0%)
7	4 (0.8%)	2 (0.7%)	0	2 (1.0%)
8	1 (0.2%)	1 (0.4%)	0	0

Values are expressed as mean ± SD; ranges, 95% confidence intervals in parentheses; OA = osteoarthritis; AVN = avascular necrosis; CCI = Charlson Comorbidity Index.

maintained on the same regimen of enoxaparin as described above until an international normalized ratio of 2.0 to 3.0 was reached. Patients with known contraindications to anticoagulation received a vena cava filter. All patients received intraoperative and/or immediate postoperative mechanical prophylaxis until discharge. Additionally, patients were mobilized postoperatively as soon as feasible to the full extent of medical safety and comfort. Screening for deep vein thrombosis or PE postoperatively was performed only for symptomatic patients.

All patients started assisted and supervised (by a fully trained physiotherapist) physiotherapy on postoperative Day 1, which consisted of early mobilization and ROM at the bed side. On postoperative Day 2, patients were transferred to the physical therapy department and started assisted ambulation with a walker, and had assisted surgical joint ROM. On postoperative Day 3, the ambulation distance was increased as tolerated. The majority of patients were discharged on postoperative Day 3 and continued physiotherapy protocols according to the disposition place (home or extended care facility).

Of the 502 patients, 465 (94%) were followed for at least 90 days, and the remaining 37 (7.4%) did not return for a formal followup but were followed in the regional health system electronic medical record. Patients were evaluated at two times, the first at 4 to 6 weeks postoperatively and the second at 12 weeks postoperatively. At the first time, all patients received standard standing knee or hip radiographs. The 37 patients who did not complete the 90-day evaluation with an orthopaedic provider either were seen or readmitted in the regional health system that allowed for the data relevant to the current study to be collected. Data were collected using information documented in the health system-wide electronic medical record, including past outpatient visits, preoperative and postoperative outpatient visits, admission notes, inpatient notes, consultation notes, operative notes, discharge summaries, rehabilitation facilities admission notes, emergency department notes, emergency department visits, physical therapy visits, and other hospitalizations notes.

The primary patient-based predictors of interest, including age, gender, and BMI, were collected before surgery. Preoperative comorbidities and complications were collected using either an established list of existing International Classification of Diseases (ICD-9) codes of medical diagnoses (Centers for Medicaid and Medicare Services – Version 25) [9] in the electronic medical record or, if not already established in the electronic medical record, then defined based on patient history using definitions of comorbidities and complications reported in the literature [12, 34, 40]. Once all the comorbidities were defined and collected, the CCI was calculated for each patient [10, 12]. The prevalence of the comorbidities was calculated and comorbidities were divided into two groups: most and least prevalent (Table 2). The complications were categorized into systemic (medical) and local (orthopaedic) and subcategorized into major or minor complications based on severity and subsequent needed interventions (Table 3). Complications were considered major if they required complex surgical or medical interventions or if they were deemed to pose a threat to the patient's life or result in functional impairment. Minor complications were those that necessitated additional observation or required medical treatment. This categorization, as described by Pulido et al. [34], was used.

Information regarding surgery (hospital, surgeon, anesthesia type, and preoperative diagnosis), hospitalization (number of transfusions, LOS, discharge disposition), readmission, and/or reoperation was collected. The primary endpoints assessed were complications (total, minor systemic, major systemic, minor local, major local), LOS, disposition (home or rehabilitation/nursing facility), and readmission and reoperation rates within 90 days of the surgery. Each patient may have had none or one or more complications. The reported complications were not mutually exclusive.

We estimated that approximately 50% of our geriatric patients experience an unwanted event after surgery based on institutional data. A sample size of 500 would support a model with 25 degrees of freedom [15]. The patient sample was analyzed using descriptive statistics of the patient and surgery variables. There were no differences in age, gender, BMI, and CCI among unilateral TKA, BL TKAs, and THA groups (Table 1).

Table 2. Comorbidity prevalence

Comorbidity	Rate
Most prevalent	
Hypertension	82%
History of smoking	52%
Coronary artery disease	25%
Anemia	24%
Diabetes mellitus	22%
Esophagogastroduodenal ulcer disease	23%
History of cancer within 5 years	20%
Osteoporosis	19%
Depression	17%
Chronic pain	14%
Connective tissue disease	10%
Steroid use	10%
History of deep vein thrombosis/pulmonary embolism	9%
Least prevalent	
Peripheral vascular disease	8%
Cerebrovascular disease	7%
Chronic obstructive pulmonary disease	7%
Congestive heart failure	7%
Renal disease	5%
Liver disease	3%
Dementia	2%
Hemiplegia	1%
Leukemia	1%
Lymphoma	1%
History of transplant	0.2%
AIDS	0.2%

Multiple univariable analyses were used to identify associations between patient variables (age, gender, BMI, CCI) and surgery variables (hospital, surgeon, diagnosis, anesthesia type) with each endpoint. These analyses were done separately for TKA and THA. Then, hierarchical stepwise multivariable regression models were used to separately analyze the association of each endpoint with the above-mentioned variables and comorbidities (Tables 1 and 2). A backward stepwise approach was used, eliminating any predictors with a p value greater than $p = 0.10$ to obtain parsimonious models. Age groups were used for the analysis, which were stratified by 10-year cohorts. The 65- to 74-year age group was used as the reference group for comparison. The strength of association between risk of complications and patient and surgery variables was calculated and reported as relative risk using a logistic or Poisson regression analysis depending on the variable

Table 3. Incidence of early complications (within 90 days postoperatively)

Complication	Number	Rate
Minor systemic	373	
Postoperative anemia	168	34%
Others*	41	8.2%
Deep vein thrombosis	30	6%
Urinary tract infection	26	5.2%
Mental status changes	25	5%
Low back pain	18	3.6%
Gastric hypomotility/ileus	16	3.2%
Atelectasis	11	2.2%
Radicular pain/sciatica	10	2%
Urinary retention/incontinence	9	1.8%
Upper respiratory infection	5	1%
Angina	4	0.8%
Pneumonia	3	0.6%
Postoperative depression	3	0.6%
Clostridium difficile infection	2	0.4%
Sinus tachycardia	2	0.2%
Major systemic	82	
Tachyarrhythmia	13	2.6%
Postoperative congestive heart failure	12	2.4%
Hypotensive crisis	10	2%
Acute renal failure	9	1.8%
Myocardial infarction	7	1.4%
Syncopal episode	6	1.2%
Death	5	1%
Pulmonary embolism	5	1%
Pulmonary edema	3	0.6%
Gastrointestinal bleeding	3	0.6%
Sepsis/multiorgan failure	3	0.6%
Stroke/transient ischemic attack	2	0.4%
Cardiac arrest/asystole	1	0.2%
Respiratory failure	1	0.2%
Seizure	1	0.2%
Bowel perforation	1	0.2%
Minor local	80	
Cellulitis/superficial infection	32	6.4%
Joint stiffness	9	1.8%
Hematoma	8	1.6%
Blisters	8	1.6%
Wound drainage	8	1.6%
Uncontrollable joint pain	8	1.6%
Bursitis/tendinitis	7	1.4%
Major local	12	
Joint infection	6	1.2%
Peripheral nerve injury	3	0.6%
Periprosthetic fracture	2	0.4%
Vascular injury	1	0.2%

* Others included vertigo, dizziness, dysphagia, thrombocytopenia, electrolyte imbalance, hypoglycemia, colitis, gastroenteritis, prolonged lower extremity/scrotal edema, vomiting, nausea, hematuria, thrombophlebitis, decubitus ulcer, heterotopic bone formation, skin rash, and pleural effusion.

type [44]. The CCI was analyzed independently from individual comorbidities. All multivariable analyses were adjusted for gender, preoperative BMI, and hospital. All statistical analyses were performed using SAS® Version 9.1 (SAS Institute Inc, Cary, NC, USA).

Results

The overall incidence of complications in the study cohort was 64%, and incidences of local complications and major complications were 19% and 11%, respectively (Table 3). Twenty-nine patients were readmitted to a hospital within 90 days of the surgery (5.8%). Eighteen patients were readmitted owing to a complication related directly to the surgery (3.6%). Of those 18 patients, 16 required a reoperation (3.2%). The transfusion rate was higher ($p < 0.001$) for patients having BL procedures when compared with patients having unilateral procedures. Five patients died within 90 days of surgery (mortality rate = 1%) attributable to massive myocardial infarction ($n = 3$), urosepsis with renal failure ($n = 1$), and lung cancer with bilateral pleural effusions ($n = 1$).

Age was a predictor of early complications after TKA and THA (Table 4). Age was not associated with LOS, disposition, readmission, and reoperation rates. In terms of complications, patients were approximately 40% more likely to have any complication per every 10 years of life (Table 5). Average BMI and gender were not good predictors of any of the endpoints measured. The CCI (range, 0–8) correlated with longer LOS (Table 5). Additionally, CCI correlated with all systemic complications, and exceptionally well with major systemic ones (Table 4). None of the variables were good predictors of disposition or readmission.

Chronic heart failure, chronic obstructive pulmonary disease, and cerebrovascular disease were the only comorbidities that correlated with longer LOS (Table 5).

Table 4. Regression models for complications

Multivariate predictor	Relative risk	95% confidence interval	p Value
TKA			
All complications			
Age (per 10 years)	1.39	1.17–1.66	0.0003
65–74 years (reference)	1.00	—	—
75–84 years	1.43	1.14–1.80	0.002
85+ years	1.25	0.79–1.98	0.35
Bilateral TKAs (versus TKA)	1.65	1.27–2.15	0.0002
Spinal anesthesia (versus other than spinal)	0.65	0.51–0.81	0.0001
*CCI (per index point)	1.18	1.11–1.26	< 0.0001
Coronary artery disease	1.73	1.36–2.21	< 0.0001
Minor systemic complications			
Bilateral TKAs (versus TKA)	1.66	1.18–2.35	0.004
Epidural (versus spinal)	1.56	1.12–2.16	0.008
*CCI (per index point)	1.13	1.03–1.24	0.008
Preoperative anemia	1.69	1.25–2.30	0.0007
Major systemic complications			
Epidural (versus other than spinal)	2.65	1.37–5.15	0.004
*CCI (per index point)	1.44	1.24–1.67	< 0.0001
Coronary artery disease	2.64	1.38–5.07	0.004
Chronic heart failure	3.15	1.43–6.93	0.005
Major local complications			
Coronary artery disease	5.81	1.27–26.54	0.02
THA			
All complications			
Age (per 10 years)	1.43	1.16–1.77	0.0008
65–74 years (reference)	1.00	—	—
75–84 years	1.45	1.08–1.94	0.01
85 + years	1.79	1.08–2.10	0.02
*CCI (per index point)	1.17	1.07–1.28	0.0006
Coronary artery disease	1.60	1.20–1.40	0.001
Major systemic complications			
*CCI (per index point)	1.73	1.39–2.15	< 0.0001
Coronary artery disease	4.31	1.62–11.44	0.003
Chronic heart failure	2.93	1.07–8.05	0.04

* CCI (Charlson Comorbidity Index) evaluated in a separate model without specific comorbidities (ie, coronary artery disease, preoperative anemia, and chronic heart failure).

In terms of complications, only patients with chronic heart failure and coronary artery disease had an association with an increased number of these events after TJA, especially major systemic ones (Table 4). Additionally, patients with coronary artery disease had an association with an increased number of major local complications, including joint infection, and were 2.6 times more likely to require reoperation after TKA (Table 5). Moreover, patients with preoperative anemia were 69% more likely to have a minor complication after TKA (Table 4). All the other comorbidities analyzed did not have an association with any of the measured adverse outcomes.

Two surgery variables had an association with complications: type of surgery (BL versus unilateral TKA) and type of anesthesia. Patients who underwent BL TKAs were 65% more likely to have any type of complication (Table 4). There were no differences between BL and unilateral procedures for all other measured endpoints. Patients who had spinal anesthesia after TKA were 65% less likely to have any type of complication (Table 4). Patients who had epidural anesthesia after TKA were 56% more likely to have a minor systemic complication and 2.6 times more likely to have a major systemic complication than patients who had spinal anesthesia (Table 4).

Table 5. Regression models for adverse outcomes

Multivariate predictor	Relative risk	95% confidence interval	p Value
TKA			
Hospital length of stay			
*CCI (per index point)	1.05	1.01–1.09	0.001
Chronic obstructive pulmonary disease	1.25	1.01–1.57	0.04
Cerebrovascular disease	1.20	1.05–1.39	0.009
Reoperation			
Coronary artery disease	2.62	0.91–7.54	0.05
THA			
Hospital length of stay			
*CCI (per index point)	1.10	1.05–1.56	< 0.0001
Chronic obstructive pulmonary disease	1.30	1.03–1.64	0.03
Chronic heart failure	1.59	1.22–2.08	0.0007

* CCI (Charlson Comorbidity Index) evaluated in a separate model without specific comorbidities (ie, chronic obstructive pulmonary disease and chronic heart failure).

Discussion

Finding the specific patient and surgical variables that play a role in the prediction of postoperative complications and mortality is paramount to improve TJAs for geriatric patients. Numerous studies have described these associations [13, 14, 16, 29–31, 34, 39, 40, 46] (Table 6). However, they were not specifically quantified, and in some cases were established using large state or federal databases that included data from low-volume hospitals, and may have missed the total accurate number of adverse events. We therefore attempted to quantify these associations in a cohort that collected adverse events in a detailed prospective manner. We specifically quantified the association of older age, increased BMI, and common comorbidities in geriatric patients undergoing TJA with early complications, increased hospital LOS, disposition to an extended care facility, and need for hospital readmission and/or reoperation.

This study has some limitations. First, we had a relatively small cohort that may not represent the general population that undergoes TKAs and THAs, which may lead the quantified risk associations to a Type II error. Second, we recognize that the CCI was designed and intended for use as a predictor of mortality and not the more broad use as a predictor of morbidity. However, we chose to include it here as it is widely used and provides a useful comparison with previous studies [16, 40].

The comprehensive documentation of any adverse events including anemia led to a higher incidence of complications than published rates [5, 13, 31, 34] (Table 6). The major complication incidence rate was 11%, which is similar to published rates [4, 6, 17] (Table 6). The incidence of major local complications (2.4%), which is

Table 6. Incidence of complications and mortality after TJA

Study	Average followup	Sample	Average age (years)	All	Local	Major	Mortality
Pulido et al. [34] (2008)	3.8 days	15383	63	10.6%	0.8%	4.4%	0.16%
Perka et al. [31] (2000)	16 days	203	67.5	9.7%	14.3%	5.5%	0
Whittle et al. [46] (1993)	30 days	6058	74	N/A	N/A	N/A	0.95%
Parvizi et al. [29] (2001)	30 days	30714	N/A	N/A	N/A	N/A	0.29%
Huddleston et al. [16] (2009)	30 days	2033	75	6.5%	N/A	N/A	0.3%
Gill et al. [14] (2003)	90 days	3048	70	N/A	N/A	N/A	0.46%
Solomon et al. [39] (2006)	90 days	9073	74.2	3.6%	N/A	N/A	0.6%
Parvizi et al. [30] (2007)	90 days	1636	64.5	32%	7.1%	7.4%	0.06%
Frosch et al. [13] (2004)	1 year	512	69.9	26.1%	15.7%	N/A	1.2%
SooHoo et al. [40] (2006)	1 year	222684	69	N/A	Infection 0.71%	Pulmonary embolism 0.4%	0.53%
Current study	90 days	502	73.2	63.9%	18.3%	10.8%	1.0%

directly related to the technical aspect of the surgical intervention, was considerably lower than reported rates [4, 6, 17]. The mortality rate is similar to reported rates [13, 14, 16, 29–31, 34, 39, 40, 46] (Table 6).

Age was an important predictor of early complications. This association has been described in numerous studies [3, 14, 30, 31, 34, 39, 40], however, it has not been quantified per each year of age and in combination with a detailed prevalence of comorbidities. This quantification may allow using this variable in risk stratification and predictive models.

The BMI was not a good predictor of any of the measured adverse outcomes or complications. Prior studies that describe the association of BMI and complications are inconclusive [11, 24, 26, 42]. Deshmukh et al. [11] and Spicer et al. [42] reported that BMI did not influence adversely the clinical outcome of TKA in the short and long-term, respectively. Miric et al. [24], on the contrary, reported a positive association between BMI and longer LOS, disposition to a rehabilitation facility, and a risk of postoperative complications. Similarly, Namba et al. [26] reported an increased infection rate in patients with a BMI greater than 35. In the current study, the lack of association between BMI and complications may be related to limited variation of BMI in the cohort, as the majority of the patients were obese.

The CCI has been used previously as a predictor of complications and adverse outcomes [16, 40]; however, to our knowledge, there are no studies that have used a detailed methodology to collect comorbidities and complications but have used state or federal discharge databases instead. These databases may lack proper documentation of all the comorbidities and complications, with ICD-9 codes and terminology, which in turn may be ambiguous and may lead to erroneous conclusions.

Chronic heart failure, chronic obstructive pulmonary disease, and cerebrovascular disease correlated with longer LOS. On the contrary, we found no association of specific comorbidities and discharge disposition. In terms of reoperation, patients with coronary artery disease were more likely to require reoperation within 90 days after TKA. This may be explained by the association between coronary artery disease and the number of required transfusions, coronary artery disease and joint infections, and coronary artery disease and major complications (Table 6). This may be attributable to the fact that these patients had more transfusions, which increased the risk of joint infection and consequently increased the risk of reoperation [18, 33]. Patients with coronary artery disease have more transfusions to maintain hemoglobin levels that prevent tachycardia and possible myocardial ischemia [41].

Only chronic heart failure and coronary artery disease were associated with an increased number of major complications. Huddleston et al. [16] described similar findings for patients undergoing TKA, especially for patients with chronic heart failure and chronic obstructive pulmonary disease. Parvizi et al. [29] reported 30-day mortality after elective THA. They reported an association of cardiorespiratory disease, including coronary artery disease, with complications and mortality. In contrast to other studies, history of smoking [25], connective tissue disease (including rheumatoid arthritis) [45], and diabetes mellitus [23] did not correlate with any complications or adverse outcomes. Finally, steroid use, history of depression, chronic pain, liver and renal disease, peripheral and cerebrovascular disease, dementia, leukemia, lymphoma, and AIDS did not have an association with adverse outcomes. The evidence in the literature in this regard is scarce and controversial [16, 31]. This may be related to the limited number of patients with these conditions undergoing TJA, which may limit the sample power to find associations. Other conditions such as hypertension and esophagogastroduodenal ulcer disease, although considered common comorbidities, once under medication control, do not seem to correlate with adverse outcomes. We believe categorization of such conditions with larger sample studies are needed to establish a better association with adverse outcomes.

Two surgery variables had association with the measured endpoints: type of surgery (BL versus unilateral TKA) and type of anesthesia. Patients who had BL TKAs were more likely to have any type of complication, especially minor systemic ones. Patients who had spinal anesthesia were less likely to have any type of complication, whereas patients who had epidural anesthesia were more likely to have a systemic complication than patients who had spinal anesthesia. These findings support those of previous studies [8, 34, 35], where BL procedures were associated with higher postoperative complications.

Overall, age, type of surgery, type of anesthesia, and some comorbidities, especially coronary artery disease and chronic heart failure, have a major role in the prediction of complications and adverse outcomes after TJA in geriatric patients. This study provides a basis for the design of a predictive model to define contraindications and develop risk stratification for geriatric patients undergoing TKAs and THAs.

Acknowledgment We thank Joseph Styron PhD, for invaluable assistance with the statistical analysis of this study.

References

1. Alfonso DT, Howell RD, Strauss EJ, Di Cesare PE. Total hip and knee arthroplasty in nonagenarians. *J Arthroplasty.* 2007;22:807–811.

2. American Academy of Orthopaedic Surgeons. Clinical Guideline on Prevention of Pulmonary Embolism in Patients Undergoing Total Hip or Knee Arthroplasty. Available at: http://www.aaos.org/research/guidelines/PE_guideline.pdf. Accessed August 27, 2010.
3. Barsoum WK, Murray TG, Klika AK, Green K, Miniaci SL, Wells BJ, Kattan MW. Predicting patient discharge disposition after total joint arthroplasty in the United States. *J Arthroplasty.* 2010;25:885–892.
4. Belmar CJ, Barth P, Lonner JH, Lotke PA. Total knee arthroplasty in patients 90 years of age and older. *J Arthroplasty.* 1999;14:911–914.
5. Berend ME, Thong AE, Faris GW, Newbern G, Pierson JL, Ritter MA. Total joint arthroplasty in the extremely elderly: hip and knee arthroplasty after entering the 89th year of life. *J Arthroplasty.* 2003;18:817–821.
6. Boettcher WG. Total hip arthroplasties in the elderly: morbidity, mortality, and cost effectiveness. *Clin Orthop Relat Res.* 1992; 274:30–34.
7. Bozic KJ, Saleh KJ, Rosenberg AG, Rubash HE. Economic evaluation in total hip arthroplasty: analysis and review of the literature. *J Arthroplasty.* 2004;19:180–189.
8. Bullock DP, Sporer SM, Shirreffs TG Jr. Comparison of simultaneous bilateral with unilateral total knee arthroplasty in terms of perioperative complications. *J Bone Joint Surg Am.* 2003;85: 1981–1986.
9. Centers for Medicaid and Medicare Services. ICD-9 Provider and Diagnostic Codes. Available at: http://www.cms.gov/ICD9ProviderDiagnosticCodes/06_codes.asp#TopOfPage. Accessed November 8, 2010.
10. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987;40: 373–383.
11. Deshmukh RG, Hayes JH, Pinder IM. Does body weight influence outcome after total knee arthroplasty? A 1-year analysis. *J Arthroplasty.* 2002;17:315–319.
12. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *J Clin Epidemiol.* 1992;45:613–619.
13. Frosch P, Decking J, Theis C, Drees P, Schoellner C, Eckardt A. Complications after total knee arthroplasty: a comprehensive report. *Acta Orthop Belg.* 2004;70:565–569.
14. Gill GS, Mills D, Joshi AB. Mortality following primary total knee arthroplasty. *J Bone Joint Surg Am.* 2003;85:432–435.
15. Harrell FE Jr, Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. *Stat Med.* 1996;15: 361–387.
16. Huddleston JI, Maloney WJ, Wang Y, Verzier N, Hunt DR, Herndon JH. Adverse events after total knee arthroplasty: a national Medicare study. *J Arthroplasty.* 2009;24(6 suppl): 95–100.
17. Joshi AB, Markovic L, Gill G. Knee arthroplasty in octogenarians: results at 10 years. *J Arthroplasty.* 2003;18:295–298.
18. Kendall SJ, Weir J, Aspinall R, Henderson D, Rosson J. Erythrocyte transfusion causes immunosuppression after total hip replacement. *Clin Orthop Relat Res.* 2000;381:145–155.
19. Kreder HJ, Berry GK, McMurtry IA, Halman SI. Arthroplasty in the octogenarian: quantifying the risks. *J Arthroplasty.* 2005;20: 289–293.
20. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am.* 2007;89: 780–785.
21. Lawrence RC, Helmick CG, Arnett FC, Deyo RA, Felson DT, Giannini EH, Heyse SP, Hirsch R, Hochberg MC, Hunder GG, Liang MH, Pillemer SR, Steen VD, Wolfe F. Estimates of the prevalence of arthritis and selected musculoskeletal disorders in the United States. *Arthritis Rheum.* 1998;41:778–799.
22. Lingard EA, Katz JN, Wright EA, Sledge CB; Kinemax Outcomes Group. Predicting the outcome of total knee arthroplasty. *J Bone Joint Surg Am.* 2004;86:2179–2186.
23. Marchant MH Jr, Viens NA, Cook C, Vail TP, Bolognesi MP. The impact of glycemic control and diabetes mellitus on perioperative outcomes after total joint arthroplasty. *J Bone Joint Surg Am.* 2009;91:1621–1629.
24. Miric A, Lim M, Kahn B, Rozenthal T, Bombick D, Sculco TP. Perioperative morbidity following total knee arthroplasty among obese patients. *J Knee Surg.* 2002;15:77–83.
25. Moller AM, Pedersen T, Villebro N, Munksgaard A. Effect of smoking on early complications after elective orthopaedic surgery. *J Bone Joint Surg Br.* 2003;85:178–181.
26. Namba RS, Paxton L, Fithian DC, Stone ML. Obesity and perioperative morbidity in total hip and total knee arthroplasty patients. *J Arthroplasty.* 2005;20(73):46–50.
27. Nilsdotter AK, Petersson IF, Roos EM, Lohmander LS. Predictors of patient relevant outcome after total hip replacement for osteoarthritis: a prospective study. *Ann Rheum Dis.* 2003;62:923–930.
28. Pagnano MW, Levy BA, Berry DJ. Cemented all polyethylene tibial components in patients age 75 years and older. *Clin Orthop Relat Res.* 1999;367:73–80.
29. Parvizi J, Johnson BG, Rowland C, Ereth MH, Lewallen DG. Thirty-day mortality after elective total hip arthroplasty. *J Bone Joint Surg Am.* 2001;83:1524–1528.
30. Parvizi J, Mui A, Purtill JJ, Sharkey PF, Hozack WJ, Rothman RH. Total joint arthroplasty: when do fatal or near-fatal complications occur? *J Bone Joint Surg Am.* 2007;89:27–32.
31. Perka C, Arnold U, Buttgereit F. Influencing factors on perioperative morbidity in knee arthroplasty. *Clin Orthop Relat Res.* 2000;378:183–191.
32. Praemer AR, Furner S, Rice DP. *Musculoskeletal Conditions in the United States*. Ed 2. Rosemont, IL: American Academy of Orthopaedic Surgeons; 1992.
33. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. *Clin Orthop Relat Res.* 2008;466:1710–1715.
34. Pulido L, Parvizi J, Macgibeny M, Sharkey PF, Purtill JJ, Rothman RH, Hozack WJ. In hospital complications after total joint arthroplasty. *J Arthroplasty.* 2008;23(61):139–145.
35. Restrepo C, Parvizi J, Dietrich T, Einhorn TA. Safety of simultaneous bilateral total knee arthroplasty: a meta-analysis. *J Bone Joint Surg Am.* 2007;89:1220–1226.
36. Roder C, Parvizi J, Eggli S, Berry DJ, Muller ME, Busato A. Demographic factors affecting long-term outcome of total hip arthroplasty. *Clin Orthop Relat Res.* 2003;417:62–73.
37. Shah AK, Celestin J, Parks ML, Levy RN. Long-term results of total joint arthroplasty in elderly patients who are frail. *Clin Orthop Relat Res.* 2004;425:106–109.
38. Simon LS. Osteoarthritis: a review. *Clin Cornerstone.* 1999;2: 26–37.
39. Solomon DH, Chibnik LB, Losina E, Huang J, Fossel AH, Husni E, Katz JN. Development of a preliminary index that predicts adverse events after total knee replacement. *Arthritis Rheum.* 2006;54:1536–1542.
40. SooHoo NF, Lieberman JR, Ko CY, Zingmond DS. Factors predicting complication rates following total knee replacement. *J Bone Joint Surg Am.* 2006;88:480–485.
41. Spahn DR, Dettori N, Kocian R, Chassot PG. Transfusion in the cardiac patient. *Crit Care Clin.* 2004;20:269–279.

42. Spicer DD, Pomeroy DL, Badenhausen WE, Schaper LA Jr, Curry JI, Suthers KE, Smith MW. Body mass index as a predictor of outcome in total knee replacement. *Int Orthop.* 2001;25:246–249.
43. St Clair SF, Higuera C, Krebs V, Tadross NA, Dumpe J, Barsoum WK. Hip and knee arthroplasty in the geriatric population. *Clin Geriatr Med.* 2006;22:515–533.
44. Wacholder S. Binomial regression in GLIM: estimating risk, ratios and risk differences. *Am J Epidemiol.* 1986;123:174–184.
45. White RH, McCurdy SA, Marder RA. Early morbidity after total hip replacement: rheumatoid arthritis versus osteoarthritis. *J Gen Intern Med.* 1990;5:304–309.
46. Whittle J, Steinberg EP, Anderson GF, Herbert R, Hochberg MC. Mortality after elective total hip arthroplasty in elderly Americans: age, gender, and indication for surgery predict survival. *Clin Orthop Relat Res.* 1993;295:119–126.
47. Wylde V, Dieppe P, Hewlett S, Learmonth ID. Total knee replacement: is it really an effective procedure for all? *Knee.* 2007;14:417–423.